PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Radar Systems

We, RAYTHEON COMPANY, a corporation organised under the laws of the State of Delaware, United States of America, of Lexington, County of Middlesex, Commonwealth of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is concerned with radar systems that simultaneously survey at a plurality of elevation angles.

A stacked beam radar configuration offers an advantage over a scanning pencil beam radar when instantaneous comparison of signal returns from different directions is required, or when coverage, data rate, or data processing requirements leave insufficient time for propagating a sufficient number of pulses from the radar to the target and back in any given observation direction. Unfortunately, however, while the scanning pencil beam radar is able to use a single sweep integrator and/or display to integrate and display the data from all elevation angles and at all ranges, the stacked beam radar requires substantial computer capacity to integrate the many signals received simultaneously in all elevation beams. This, of course, increases the relative complexity, size and cost of the stacked beam radar system.

Accordingly, a primary object of the present invention is to provide an improved radar system which simultaneously surveys at a plurality of elevation angles and, more particularly, one that is comparatively simple.

According to the present invention there is provided a pulse radar system comprising a transmitter for simultaneously transmitting a radar pulse of duration T seconds along x radar beams at different elevation angles, a receiving arrangement comprising means for directing radar return signals incident upon the receiving arrangement at various elevation angles into corresponding ones of x lines, filter means interposed in each line for shaping the radar return signal and further having a frequency bandwidth of k/T cycles per second, where k is a constant, and means for time multiplexing the filtered signals in such a manner that the width of each multiplied signal is substantially equal to T/x seconds.

A preferred embodiment of the invention includes a radar antenna for simultaneously providing a plurality of echo signals, a beam-forming matrix and a narrow-band I.F. amplifier network having a plurality of predetermined bandwidths, and a commutator for selectively passing part of each echo signal once during each pulse length for the duration of the radar ranging interval. Thus, the commutator selectively multiplexes the echoes and generates an output signal which is applied by a single cable to wide-band sweep integration and display units. Although the echo length is greatly reduced, the signal detectability is degraded by only a very small amount.

The invention will be described, by way of example, with reference to the accompanying drawings, wherein the single Figure is a block diagram of the preferred embodiment of the invention.

This embodiment comprises a beam-forming matrix 12 connected between an antenna 10 and an intermediate-frequency amplifier network 14, a commutator 16 connected to the amplifier network 14, and a sweep integrator 18 connected between the commutator 16 and a display unit 20. The antenna 10 and the beam-forming matrix 12 may take any one of a variety of forms. Some examples are a doubly curved reflector with a set of feed horns, a singly curved reflector with an array of wide angle horns connected to a Butler matrix, or a planar array with individual rows connected to a tapped delay

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line beam-forming matrix. The antenna 10 is used for both transmit and receive employing conventional radar duplexing techniques. The intermediate-frequency amplifier network 14 may comprise a plurality of narrow-band tuned pentode amplifier stages for selectively passing the echoes. The commutator 16 is an electrical switching device and may include, for instance, a diode gating matrix. The sweep integrator 18 may comprise a wide-band delay line integrator. The display unit 20 may include a well-known range height indicator and plan position indicator.

A block diagram approach has been followed herein with a detailed functional description of each block and specific identification of the devices it represents in order to prevent undue burdening of the description with matter within the knowledge of those skilled in this art. Thus, the individual is free to consult any of the available electrical treatises for a more detailed description of these well-known blocks, such as "Introduction to Radar Systems", by Merrill I. Skolnick, published by McGraw-Hill Book Company, Inc. in 1962, and which is incorporated herein by reference.

The antenna 10 receives an illumination pulse of length τ from a plurality of x overlapping beams which extend into space, each beam being positioned to illuminate an area at a different elevation. Whenever one of these beams intercepts a target, an echo signal is received by the antenna 10 and generated on one of x lines 22. Consequently, a plurality of signals may be generated simultaneously on the lines 22 because more than one target is present or because more than one beam intercepts a single target.

The echo signals from the antenna 10 are applied by the lines 22 to the beam-forming matrix 12 which generates each echo signal on that one of x lines 24 which corresponds to the elevation angle where the target is located upon being intercepted. The echoes are then transferred by the lines 24 to the I.F. amplifier network 14. As was stated previously, the antenna 10 has an illumination pulse length of τ. Each one of the intermediate-frequency amplifiers in the network 14 acts as a filter with a bandwidth of $1.2/\tau$. The echo signals from the intermediate-frequency amplifier network 14 are applied to the commutator 16 by way of lines 26.

The commutator 16 comprises an electrical switch which produces an output signal of maximum length τ that is made up of selected portions of a plurality of echoes. An echo signal is a beam at any elevation angle produces an echo signal of length τ/x at an output line 30 of the commutator 16. Thus, the commutator 16 allows only a selected portion of each echo signal to pass. This is accomplished in the following manner. As was stated above, the commutator 16 comprises an electrical switch including a diode gating matrix (not shown). Each diode is selectively opened for a time duration equal to τ/x so that only a portion of each echo is allowed to pass through to output line 30. Accordingly, the diodes of the diode gating matrix are successively opened over the duration τ of one pulse, and the output signal generated on the line 30 includes a selected portion of each echo signal received by antenna 10. Consequently, the antenna output signals are commutated once in every pulse length for the duration of the radar ranging interval. The commutator 28 also generates a pulse train which is applied through a line 28 to the display unit 20, thus indicating at which elevation angles the received echoes were produced.

The sweep integrator 18 includes a wide-band delay line integrator for summing successive sweeps as the antenna 10 scans in azimuth in order to improve the detection capability of the receiving system. The summed echo signals are then transferred by a line 32 to the display unit 20. The unit 20 includes a range height indicator (not shown) for displaying range and height, and a plan position indicator (not shown) for displaying angle and range on a polar display, both using well-known display techniques.

Accordingly, the stacked beam echo signals are selectively commutated once in each pulse length for the duration of the radar ranging interval. Thus, a single sweep integrator and/or display may be used to integrate and display the data from all elevation angles and at all ranges. This advantage is achieved at the expense of only an insignificant loss in signal detectability, since the signal to noise ratio has been established in the narrow-band amplifiers prior to the commutative process.

Although the invention has been described with reference to a preferred embodiment, it should be appreciated that the invention is not limited thereby. For example, the above-mentioned loss in signal detectability can be even further reduced if more than one sample is taken of each echo. This may be accomplished, for instance, through the use of more than one commutator or of one commutator operated at double the switching rate. In addition, it is possible to interchange the beam-forming matrix 12 and the intermediate-frequency amplifier network 14. A stacked-beam antenna which performs beam-forming prior to transmission may be used. The wide-band sweep integrator 18 may operate upon video signals instead of upon intermediate-frequency signals. Furthermore, the commutator 16 may include any of the well-known electrical switches.

WHAT WE CLAIM IS:—

1. A pulse radar system comprising a transmitter for simultaneously transmitting a radar

pulse of duration T seconds along x radar beams at different elevation angles, a receiving arrangement comprising means for directing radar return signals incident upon the receiving arrangement at various elevation angles into corresponding ones of x lines, filter means interposed in each line for shaping the radar return signal and further having a frequency bandwidth of k/T cycles per second, where k is a constant, and means for time multiplexing the filtered signals in such a manner that the width of each multiplexed signal is substantially equal to T/x seconds.

2. A radar system according to claim 1, wherein the means for directing the radar return signals comprises a beam-forming matrix coupled to a planar antenna array.

3. A radar system according to claim 1 or 2, wherein the filter means is included in an intermediate frequency amplifier.

4. A radar system according to claim 1, wherein k is substantially equal to 1.2.

5. A radar system substantially as hereinbefore described with reference to the accompanying drawing.

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1 SHEET *This drawing is a reproduction of the Original on a reduced scale*